Reference Loads for the Downhole Pump Card

Lynn Rowlan

ECHOMETER
Dynamometer Card Definition

1) **Surface dynamometer card** is the plot of the measured rod loads at the various positions throughout a complete stroke; the load is usually displayed in pounds of force and the position is usually displayed in inches.

2) **Pump dynamometer card** is a plot of the calculated loads at various positions of pump stroke and represents the fluid load the pump applies to the bottom of the rod string.
Reference Loads for the Downhole Pump Card

Understanding the pump card basic loads is critical to analyzing and troubleshooting downhole problems:

- **Fo Max**
- **Fo From Fluid Level**
- **Zero Load**
Pump Card Reference:

Zero Load Line ~ Down Stroke
Fo From Fluid Level ~ Up Stroke

Normal Pump Card Loads:
SV Open Upstroke:
Fo Max = (Pdis – 0)*Ap
Fo = (Pdis - Pintk)*Ap

TV Open Downstroke:
Fo = 0

Reference Lines:

1. **Fo Max** - assumes pump intake pressure is zero, where well provides no help in lifting the fluid to the surface.

2. **Fo From Fluid Level** - assumes pump intake pressure determined from fluid level shot, where well's PIP provides help in lifting the fluid.

3. **Zero Load Line** - assumes pressure above and below the plunger are equal; no friction due to fluid displacing through SV on down stroke.

Fo ~ Height of Pump Card
Fluid Load Lifted by Rods

Well

<table>
<thead>
<tr>
<th>Fo Max</th>
<th>Wrf + Fo Max</th>
<th>Fo From Fluid Level</th>
<th>Wrf</th>
</tr>
</thead>
<tbody>
<tr>
<td>156.0</td>
<td>168.0</td>
<td>17.50</td>
<td>10.00</td>
</tr>
<tr>
<td>17.50</td>
<td>20.00</td>
<td>15.00</td>
<td>12.50</td>
</tr>
<tr>
<td>20.00</td>
<td>22.50</td>
<td>17.50</td>
<td>15.00</td>
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<td>22.50</td>
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<td>25.00</td>
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<tr>
<td>27.50</td>
<td>30.00</td>
<td>30.00</td>
<td>30.00</td>
</tr>
</tbody>
</table>

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Steps in the Pump Operation

Zero Load Line  
Load Reference Line ~ Down Stroke

D) Pump discharge pressure (Pdis) equals the static tubing pressure (Pb), and the traveling valve opens. Pdis now carried by tubing.

D - A, the fluid in the pump is displaced through the traveling valve into the tubing and ZERO fluid load is on rods.

SANDIA Pump Card
**Steps in the Pump Operation**

**Up Stroke**

- **B**) Standing Valve opens, when rods stretch to pick up fluid load, $F_o$, from tubing.
- **C**) Standing valve closes.

**Equation**: 

$$F_o = (P_{dis} - P_{intk}) \times \text{Area Pump}$$

**Pump Card**

- **After TV Closes and SV Opens:**
  - $P_{dis} > P_b$
  - $P_b = P_{intk}$

**B-C**) Plunger applies Fluid load, $F_o$, to the rods as well fluids are drawn into the pump.
Acoustic PIP Calculation

- Requires stabilized conditions
- **Determination of Liquid Level Depth**
  - Avg. Joint Length, Acoustic Velocity, SG Gas ....
- Measurement of casing pressure
- **Tubing, Casing Size, & Pump Depth**
- Oil, water and annular gas densities
- Measurement of casing pressure buildup rate (at Producing Conditions)
Pump Discharge Pressure, $P_{dis}$

- Tubing Pressure
- Flow rate $Q$
- Tubing Fluid Gradient
- Producing Fluid Level
- Pdis
- PIP
- PBHP
- SBHP
- Drawdown
- Pressure
Pump Discharge Pressure

- Requires stabilized conditions
- Measurement of tubing pressure
- True Vertical Pump Depth
- Oil, water and gas densities
- Oil, water, and gas Production Rate
- Tubing Fluid Gradient

\[ Fo = (P_{\text{dis}} - P_{\text{int}}) \times \text{Area Pump} \]
Damping Coefficients

0.05 Default Damping
NOT Enough

Damping = 0.22
OK

Pump Depth = 8892 ft

330 BOPD 37 BWPD
10 Deg API Gravity
Abnormal Loads – Tight Stuffing Box

Normal

Too Tight

Extra Load from Friction
Tubing Fluid Gradient – Wrf & Pdis

Grad = 0.3 psi/ft
## Flat Pump Card Load Lines

1. **TV Stuck Open** - Looks like Deep Rod Part but you can often tag or jar the rods and knock the debris out of the pump and re-start pump action.

2. **Deep Rod Part** – Plots on the Zero Load Line

3. **Shallow Rod Part** – Plots below the Zero Load Line by the amount of missing rod weight in fluid no longer attached to the polished rod.

4. **Tubing Blown Dry** – Plots as a flat line @ a height of Wra-Wrf pounds above the zero load line.

5. **SV Stuck Open** – Plots on the Fo from the Fluid Level line.

6. **Blocked Intake** – No fluid entry into pump and low slippage through pump clearances.
Horse Shoe Pump Card
Flat Load Lines

- SV Stuck Shut - No Flow into Pump
- SV Stuck Open and You Catch It
- Tubing Blown Dry
- TV Stuck Open OR Deep Rod Part
- Shallow Rod Part

Kt
Fo Max
44.6
Lost TV Load

Lost TV Load

Strokes 10 seconds apart.
Is this a deep Rod Part?

Stroke 11

Stroke 13
Figure 1: Graph showing the load (Klbs) over time and position (inches)

**Trash in TV** Notice normal appearing Surface Dynamometer Card, on the 13th stroke TV became stuck open due to trash. Same type of surface card could occur, if Pump unseated, Pull Rod became unscrewed or parted, or rods parted at the pump.
SV Sticks Open  Strokes 29-34 SV Missing
SV Sticks Open ~ TV OK?

PRT Pump Card Always on Zero Load Line

Polished Rod Transducer

Horse Shoe Load Cell
SV Stuck Closed ~ TV OK?

Tight Clearances
Blocked Intake w/ No Fluid Entry; Then Pump Card @ Fo Max

Pump Card Between Zero Load Line and Fo From Fluid Level
No fluid load from pump being applied to rod string. Parted rods are overtravel cards, because there is no loss of downhole stroke due to the static stretch of rods picking up fluid load. Measured surface dynamometer card loads are near standing valve load (Wrf).

Note that both the standing and traveling valves measured test loads are at the calculated standing valve test load.

Sometimes trash in the pump keeps the traveling valve ball from going on seat. Tagging on the down stroke before pulling, may knock out trash.
Missing 37 3/4" Rods Parted @ 5365'

Pump Card Sets Below the Zero Load Line By Weight of Missing Rods

Missing: Wrf 3536 lbs

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Missing 37 3/4" Rods

Adjusted Rod Length, then Pump Card sets on Zero Load Line

No Pump No Fo Rods

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Buoyancy – Tubing Fluid Gradient

**Tubing Fluid Gradient** = 0.432

- **Wra = 11942**
- **Fo Max**
- **TV (measured)**
- **Wrf**
- **Fo From Fluid Level**
- **Fbuoy = Wra - Wrf**
- **Fbuoy = 1518**

**Tubing Fluid Gradient** = 0.0

- **Wra = 10424**
- **Fo Max**
- **TV (measured)**
- **Wrf**
- **Fo From Fluid Level**
- **Fbuoy = Wra - Wrf**
- **Fbuoy = 1518**
Rods Lighter than Wra because Rods Above Hole in Air and Rods Below Hole Rods in Fluid

Missing Buoyancy

Rod Loads Heavier than Wrf

Missing Buoyancy
## Location of Pump Card with Respect to Basic Loads are Critical to Analysis

1) Location of Pump Load can be Used to Identify and Troubleshoot Problem in the Well.

2) Pump card that plots as a flat line could be:

<table>
<thead>
<tr>
<th>Condition</th>
<th>Description</th>
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<tbody>
<tr>
<td>TV Stuck Open</td>
<td>Tubing Dry</td>
</tr>
<tr>
<td>Deep Rod Part</td>
<td>SV Stuck Open</td>
</tr>
<tr>
<td>Shallow Rod Part</td>
<td>Blocked Intake</td>
</tr>
</tbody>
</table>

3) OK Pump Card should plot between Zero Load Line and Fo from Fluid Level Line

4) If Polished Rod Transducer used to acquire dynamometer data **and pump card is flat**
   - Difficult to identify problem
   - All of the loads plot on the zero load line.
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